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Genetic parameter estimates for growth traits and Kleiber ratio in Hairy goat in Türkiye

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ABSTRACT: This research was carried out to evaluate the environmental factors affecting the growth characteristics and Kleiber ratio (KR) in Hair goats and to estimate the growth related genetic parameters. The fixed effects included in the analysis were flock-year of birth, birth season, age of mother, type of birth and sex of kids. The all fixed factors were significant on live weight of kids and KR before and after weaning ($P<0.05$). Direct heritabilities were 0.27, 0.23, 0.23, 0.22, 0.21, 0.39, 0.37 and 0.20 for birth weight (W0), weight at 60 days of age (W60), daily weight gain from birth to 60 days of age (DWG60), weight at 120 days of age (W120), daily weight gain from birth to 120 days of age (DWG120), weight at 180 days of age (W180), Kleiber Ratio at 60 days of age (KR60) and Kleiber Ratio at 120 days of age (KR120), respectively. The genetic and the environmental correlations among all traits were positive, except for W0 that environmental correlations between W0 with the all other traits were small and negative. Based on the results in this study, it was concluded that it will be more effective to select kids based on KR60 in order to increase body weight at butchery, and can be used as a feed efficiency indicator for preweaning growth characteristics in the selection index. In addition, the estimates of genetic parameters indicated that this goat population had the genetic potential to improve its growth traits.

Keyword: Genetic parameters; Growth; Hairy goat; Kleiber ratio; Selection.

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INTRODUCTION

For any goat producers for meat, profitability is the most important issue affected by growth traits early in life of animals, and the cost of raising kids can be decreased with a high growth rate during the pre-weaning period (Niek erk and Casey, 1988). Kids' growth performance after weaning builds on their growth performance before weaning (Adenaike and Bemji, 2011). The early growth traits of kids are determined by their genetic structure, maternal genetics and maternal permanent environmental effect (Mandal et al., 2006). Hairy goat is considered as the best known native Turkish goat breed and raised all around the country especially in the mountains areas and also plays major role in meat, milk and hair production (multi-purpose). Animal-derived foods, especially meat and milk are very important in human nutrition. Hair goats contribute to their owners and to the national economy with their product (Tekin and Arlı, 2019; Oyan et al., 2024), and based on the national database (TUIK, 2023) red meat and milk production were 128 898 and 42 528 tons from hairy goat in Türkiye, respectively.

In any intended selection program, improvement of growth performance is necessary to achieve maximum weaning weight. This may be possible by including a trait such as the Kleiber ratio (KR) in the selection program. In selection programs, it is almost impossible to determine the feed consumption of animals in the pasture. KR, which is defined as the relationship of growth rate with metabolic weight, was developed as an alternative ratio to solve this problem in pasture animals (Arthur et al., 2001), since it does not require individual measurement and allows to classify animals with relatively high growth efficiency by body size relative to body size (Kleiber 1947). In addition, Köster et al. (1994) suggested that KR is a useful indicator of growth efficiency and an important selection criterion for growth efficiency. Arthur et al. (2001) found a strong correlation between KR and feed conversion ratio in bull (-0.81). Also, since animals differ in their individual abilities, using feed efficiently by selecting the most productive animal results in a significantly lower production cost (Ghafouri-Kesbi et al., 2011). Scholtz et al. (1990) supported that KR could be used as an indirect selection parameter for feed conversion. Animals with a high KR are considered animals with a high feed rating (Ghafouri-Kesbi et al., 2011). Also, knowing genetic parameters such as heritability and genetic correlations between traits, making genetic improvement in growth in a selection program, is necessary to create efficient selection indices.

Recently, Hairy goat has been included in "the National Genetic Improvement Project of Sheep and Goat in Farmer Conditions (NGIPSG)" in Türkiye which has been supported by the General Directorate of Agricultural Research and Policies (TAGEM), the Ministry of Agriculture and Forestry. The project has been applied in 55 cities including approximately 1 200 000 heads of sheep and goat (23 sheep and 7 goat breeds).

The project started in 2005 and uses pure breeding and selection methods, which are frequently used in animal breeding. Some characteristics such as meat and milk yield are recorded from the animals in the project. In Hair goats, the live birth weight and weaning weight of the kids born for growth characteristics are weighed and recorded. As a result of statistical calculations used in animal breeding, individual breeding values are determined. The selected kids constitute the next Hair goat generation. The one of the ongoing sub-project of this national project has been carriet out in Kahramanmaraş region from 2014 to 2018. Basic methodology applied during the project was the selection of animals with high breeding values adjusted from all non-additive genetic effects. Breeding values are affected by non-genetic factors and must be adjusted to obtain true genetic evaluation (Djemali and Berger, 1992). Moreover, several other factors affect the genetic evaluation such as methodology used to obtain the estimates of genetic parameters (Luch 1949). A large number of studies has investigated the ideal or true model to estimate the genetic parameters for growth traits controlled by maternal effects in goats (Bosso et al., 2007; Boujenane and Hazzab, 2008; Gholizadeh et al., 2010; Rashidi et al., 2011; Sadegh et al., 2013; El-Awady et al., 2019).

Therefore, the objective of the present study was to estimate genetic parameters (such as heritability, genetic correlation etc.) for pre and post weaning growth traits and Kleiber Ratio (KR) in Hairy goats under farmer conditions in Kahramanmaraş region in Türkiye. It is expected that the information obtained from the current study will help in the establishment of breeding programs to bring desirable genetic improvement in the Hairy goat breed in Türkiye.

MATERIALS AND METHODS

Animals and data set

This study was carried out in Kahramanmaraş Province (37° 50′ N and 36° 31′ E) (Figure 1) by the Ministry of Agriculture and Forestry (MoAF),

Figure 1. Villages of Kahramanmaraş province where the study was conducted.

General Directorate of Agricultural Research and Policies (TAGEM) (Güngör et al., 2021). The data of the study was from kids born in 49 flocks in 14 villages of Onikişubat district between the years 2014 and 2018. The traits included in this study were birth weight (W0, n=19386), live weight at 60 days of age (W60, n=5037), live weight at 120 days of age (W120, n=9902), live weight at 180 days of age (W180, n=3849), daily weight gain from birth to 60 days of age (DWG1), daily weight gain from birth to 120 days of age (DWG2), Kleiber ratio at 60 (KR60) and 120 days of age (KR120). Kleiber ratios (KR60 and KR120) were computed as KR60=DWG1/W60^0.75 and KR120=DWG2/W120^0.75 according to Kleiber (Kleiber 1947). Details of data structures for the hairy goat population are given in Table 1.

Statistical analyses

The GLM method of SAS (SAS 2017) were used to determine the significant environmental factors on the growth and KR which stands for feeding efficiency traits. The models included the flock-year of birth, birth season (winter or spring), birth type, age of mother and sex of kids. Birth type was coded as single and multiple, sex as male and female.

The variance-covariance components were estimated with animal model using the MTDFREML software (Boldman et al., 1995) and first using a single trait animal model and five different statistical models. Direct and maternal additive genetic effects and maternal permanent environmental effects were included as random effects in the animal models. After the choosing the best fitted model for each trait, bivariate analyses were conducted to obtain genetic and environmental correlations between the traits. The models used in single trait analysis were:

Model 1: $y = Xb + Z_1 a + e$

Model 2: $y = Xb + Z_1 a + Z_2 m + e$ Cov(a,m)=0

Model 3: $y = Xb + Z_1 a + Z_2 m + e$ Cov(a,m)≠0

Model 4: $y = Xb + Z_1 a + Wpe + e$

Model 5: $y = Xb + Z_1 a + Z_2 m + Wpe + e$ Cov(a,m)≠0

X, Z1, Z2 and W were design matrices for fixed, direct and maternal genetic effects, and permanent environmental effects of goats, respectively. b, a, m, pe and e symbols represent for fixed, direct and maternal additive genetic effects, maternal environment effects and residual effects for each individual, respectively.

It was assumed that the random effects in the mo-

Table 1. Descriptive statistics and data structure

	n	#Sire	#Dam	$\bar{X} \pm SH$	Min.	Max.	CV%
W0	19331	269	10362	3.23±0.005	1.11	5.30	21.39
W60	5037	180	3616	12.16±0.039	6.15	21.05	23.01
W120	9902	213	6797	20.26±0.048	9.54	34.68	23.36
W180	3849	69	3119	30.82±0.109	13.04	51.01	22.04
DWG60	5037	180	3616	148.97±0.637	42.86	278.40	30.36
DWG120	9894	213	6797	141.65±0.386	46.08	259.43	27.13
KR60	5037	180	3616	22.49±0.046	10.10	30.58	14.56
KR120	9893	213	6797	14.66±0.016	8.34	18.50	10.65

W0: birth weight, W60: weight at 60 days, W120: weight at 120 days, W180: weight at 180 days, DWG60: daily weight gain from birth to 60 days, DWG120: daily weight gain from birth to 120 days, KR60: Kleiber ratio at 60 days, KR120: Kleiber ratio at 120 days, Min: minimum value, Max: maximum value, CV%: coefficient of variation

del were normally distributed with mean 0 and variances $V(a) = \boldsymbol{A}\sigma_a^2$, $V(m) = \boldsymbol{A}\boldsymbol{\sigma}_m^2$, $V(pe) = \boldsymbol{I}_n\sigma_{pe}^2$ and $V(e) = \boldsymbol{I}_n\sigma_e^2$, where I_n was identity matrix with order of number of records. The σ_a^2, σ_m^2, σ_{pe}^2 and σ_e^2 were direct and maternal genetic, maternal environmental and residual variance, respectively. The **A** was the numerator relationship matrix from pedigree information. Finally, $\sigma_{a,m}$ was the additive genetic covariance between direct (a) and maternal (m) additive genetic effects.
For all of the analyses, the convergence criterion was set to 10^{-9}.

The total heritability (h_t^2) was estimated as (Willham 1972):

$$h_t^2 = \left(\frac{\sigma_a^2 + 0.5\sigma_m^2 + 1.5\sigma_{a,m}}{\sigma_P^2}\right)$$

where σ_P^2 is te phenotypic variance and the other terms are same as described above.

RESULTS AND DISCUSSION

Least Square Means and Effect of Fixed Factors

The least squared means ± SE of the growth characteristics are given in Table 2. These fixed effects have been observed as a significant source of environmental variation (P<0.05). For all traits in this study, weaned kids born and weaned by multiparous goats had a significantly higher live weight, daily weight gains and Kleiber Ratio (P<0.05) than those born and weaned by goats given birth for the first time. It can be attributable to that multiparous goats have high maternal performance (Mourad 1994; Supakorn and Pralomkarn, 2012). At the same time, it has been observed that male kids have higher values in terms of all traits compared to female kids, and singleton kids compared to multiple kids (P<0.05). The differences between the sexes increased with the growth rate, this result can be attributed to the fact that male kids are more sensitive to environmental developments and have higher W0 compared to females (Supakorn and Pralomkarn, 2012; Amoah et al., 1996). The results obtained in this study show that males are more advantageous and these results can be compared with other goat breeds (Portolano et al., 2002). Portolano et al. (2002) reported that singleton kids are heavier than twins and twins are heavier than triplets, and their body weight traits are affected by their mothers' litter size. Kids born in spring have higher values than kids born in winter in terms of all traits except for W180. Similar results were reported by Supakorn and Pralomkarn (2012). The effect of the season can be partially explained by climatic conditions and epidemics in the periods. Moreover, the significant effect of the season on kid body weights has been reported in several other studies (Supakorn and Pralomkarn, 2012; Malik et al., 1986; Warmington and Kirton, 1990; Gebrulul et al., 1994).

Finally, the regression of traits on birth weight (W0) was found to be highly significant (P<0.01). Therefore, this regression has been taken into account in the estimation of genetic parameters, as they can possibly reduce some random errors.

Model Selection

First, univariate analyses were performed with five different single trait animal model for each trait and the results are given in Table 3. In this study, direct and maternal additive genetic effects, maternal permanent environmental effects, and models with and without additive genetic covariance between direct and maternal effects were considered. In single trait analysis, the models written in italic form (Table 3) did not converge et al: Models 2, 3, 4 and 5 for KR60 and KR120; Models 3, 4 and 5 for W180; Model 5 for W60, W120, DWG60 and DWG120, respectively. The models with permanent environmental effect (pe) highly underestimated the direct heritabilities (h^2) and produced larger residual variance (σ_e^2) Similarly, the models with maternal additive genetic effect (m), with or without covariance with direct additive genetic effect ($\sigma_{a,m}$) also severely underestimated the direct heritabilities, and the severeness was more obvious for W120 and DWG120. In general for this study, it was observed first that the models including both maternal genetic (m) and environment effects (pe) create confounding problem for this data structure. Second, the models with direct genetic (a) and pe highly underestimated the h^2 . Third, the models with m, with or without $\sigma_{a,m}$ underestimated direct and total heritabilities (h_t^2). Moreover, for W0, convergence criteria were met for all five models, but if the model included all random effects at the same time, h^2 was highly underestimated. The models with maternal permanent environmental effects did not fit the data structure in this research. Similar recurrence was reported previous study conducted by Supakorn and Pralomkarn (2012). On the other hand, Mohammadi et al. (2010) reported that the permanent maternal environment effect was effective on KR in sheep.

The most suitable model for each trait was de-

Table 2. Least square means and standard error of the traits in the analyses by environmental factors

	W0	W60	W120	W180	DWG60	DWG120	KR60	KR120
	$\bar{X} \pm SH$	$\bar{X} \pm SH$	$\bar{X} \pm SH$	$\bar{X} \pm SH$	$\bar{X} \pm SH$	$\bar{X} \pm SH$	$\bar{X} \pm SH$	$\bar{X} \pm SH$
Year								
2014	3.16±0.012^{a}	11.63±0.137^{a}	20.56±0.147^{a}	27.82±0.411^{a}	140.01±2.290^{a}	144.22±1.226^{a}	21.84±0.163^{a}	14.77±0.050^{a}
2015	3.23±0.011^{b}	11.84±0.231^{a}	19.29±0.141^{b}	26.12±0.390^{b}	143.65±3.850^{a}	133.63±1.168^{b}	21.99±0.274^{a}	14.33±0.048^{b}
2016	3.17±0.012^{a}	11.58±0.124^{a}	20.70±0.176^{a}	25.25±0.626^{b}	139.27±2.063^{a}	145.19±1.466^{a}	21.72±0.147^{a}	14.79±0.060^{a}
2017	3.07±0.013^{c}	11.45±0.134^{a}	19.47±0.169^{b}	30.97±0.462^{c}	137.05±2.239^{a}	134.80±1.403^{b}	21.51±0.159^{a}	14.28±0.058^{b}
2018	3.08±0.015^{c}	13.36±0.160^{b}	21.58±0.248^{c}	32.45±0.431^{c}	168.91±2.665^{b}	152.78±2.067^{c}	23.58±0.190^{b}	15.10±0.085^{c}
Season								
Winter	3.18±0.007^{a}	11.79±0.127^{a}	19.71±0.121^{a}	28.62±0.254	142.78±2.115^{a}	137.16±1.003^{a}	21.98±0.151^{a}	14.49±0.041^{a}
Spring	3.10±0.013^{b}	12.15±0.128^{b}	20.93±0.175^{b}	28.42±0.504	148.77±2.135^{b}	147.09±1.451^{b}	22.28±0.152^{b}	14.81±0.059^{b}
Age of Mother								
2	3.06±0.012^{a}	11.40±0.132^{a}	19.53±0.149^{a}	27.54±0.374^{a}	136.30±2.196^{a}	135.47±1.237^{a}	21.47±0.156^{a}	14.39±0.051^{a}
3	3.11±0.012^{b}	12.00±0.138^{b}	20.32±0.151^{b}	28.32±0.369^{ab}	146.29±2.297^{b}	142.13±1.255^{b}	22.14±0.163^{b}	14.65±0.051^{b}
4	3.16±0.012^{c}	12.11±0.135^{b}	20.30±0.149^{b}	28.93±0.391^{bc}	148.10±2.257^{b}	141.99±1.241^{b}	22.28±0.161^{b}	14.65±0.051^{b}
5	3.19±0.013^{c}	12.25±0.150^{b}	20.66±0.159^{b}	28.88±0.388^{bc}	150.41±2.516^{b}	145.02±1.321^{b}	22.49±0.179^{b}	14.77±0.054^{b}
6	3.16±0.015^{c}	11.91±0.151^{b}	20.65±0.175^{b}	28.25±0.431^{bc}	144.68±2.520^{b}	144.89±1.454^{b}	22.06±0.179^{b}	14.77±0.060^{b}
7	3.17±0.014^{c}	12.16±0.156^{b}	20.46±0.165^{b}	29.20±0.378^{c}	148.87±2.605^{b}	143.24±1.374^{b}	22.35±0.185^{b}	14.70±0.056^{b}
Birth Type								
Single	3.30±0.008^{a}	12.33±0.117^{a}	21.19±0.122^{a}	29.55±0.319^{a}	151.72±1.944^{a}	149.32±1.017^{a}	22.58±0.138^{a}	14.94±0.042^{a}
Multiple	2.98±0.012^{b}	11.61±0.137^{b}	19.46±0.153^{b}	27.50±0.373^{b}	139.83±2.283^{b}	134.92±1.271^{b}	21.68±0.162^{b}	14.37±0.052^{b}
Sex								
Female	3.01±0.009^{a}	11.51±0.124^{a}	19.19±0.134^{a}	26.47±0.340^{a}	138.01±2.060^{a}	132.79±1.110^{a}	21.60±0.147^{a}	14.30±0.045^{a}
Male	3.27±0.010^{b}	12.44±0.123^{b}	21.45±0.132^{b}	30.58±0.337^{b}	153.54±2.055^{b}	151.45±1.095^{b}	22.66±0.146^{b}	15.00±0.045^{b}
β_{W0}		1.12±0.067**	1.22±0.077**	1.22±0.177**	2.12±1.115	2.01±0.644**	-1.37±0.079**	-0.49±0.026**

Table 3. Model parameters for growth traits in Hairy goat in Türkiye

Özellik		h^2	m^2	$r_{a,m}$	pe²	e^2	h_t^2	-2LogL	AIC	BIC
	Model1	0.27				0.73	0.27	-3324	3328	-3304
	Model2	0.06	0.09			0.86	0.10	-3334	3340	-3304
W0	Model3	0.20	0.17	-0.64		0.75	0.11	-3340	3348	-3301
	Model4	0.11			0.08	0.81	0.11	-3377	3383	-3347
	Model5	0.08	0.02	0.08	0.06	0.83	0.12	-3339	3349	-3290
	Model1	0.23				0.77	0.23	12833	-12829	12850
	Model2	0.11	0.06			0.83	0.14	12812	-12806	12838
W60	Model3	0.14	0.11	-0.47		0.81	0.11	12812	-12804	12846
	Model4	0.05			0.08	0.87	0.05	12821	-12815	12847
	Model5*	0.17	0.30	1.00	0.01	0.31	0.65	13254	-13244	13297
	Model1	0.23				0.77	0.23	40090	-40086	40107
	Model2	0.11	0.06			0.83	0.14	40013	-40007	40039
DWG60	Model3	0.14	0.11	-0.47		0.81	0.11	40012	-40004	40046
	Model4	0.05			0.08	0.87	0.05	40078	-40072	40104
	Model5*	0.14	0.11	-0.47	0.01	0.81	0.11	40011	-40001	40054
	Model1	0.22				0.78	0.22	35309	-35305	35327
	Model2	0.03	0.09			0.89	0.07	35253	-35247	35281
W120	Model3	0.06	0.16	-0.79		0.86	0.02	35252	-35244	35289
	Model4	0.06			0.08	0.86	0.06	35288	-35282	35316
	Model5*	0.06	0.14	-0.76	0.01	0.86	0.02	35249	-35239	35295
	Model1	0.21				0.79	0.21	76276	-76272	76294
	Model2	0.02	0.09			0.89	0.07	76172	-76166	76200
DWG120	Model3	0.05	0.18	-0.96		0.86	0.14	76170	-76162	76207
	Model4	0.05			0.08	0.86	0.05	76253	-76247	76281
	Model5*	0.05	0.13	-0.89	0.03	0.86	0.01	76167	-76157	76213
	Model1	0.39				0.61	0.39	16299	-16295	16316
	Model2	0.36	0.01			0.63	0.37	16294	-16288	16319
W180	Model3*	0.86	0.16	-0.75		0.26	0.53	16293	-16285	16326
	Model4*	0.26			0.05	0.69	0.26	16293	-16287	16318
	Model5*	0.03	0.05	1.00	0.02	0.86	0.11	16268	-16258	16309
	Model1	0.37				0.63	0.37	14456	-14452	14473
	Model2*	0.43	0.00			0.57	0.43	14415	-14409	14441
KR60	Model3*	0.31	0.00	1.00		0.66	0.35	14394	-14386	14428
	Model4*	0.35			0.01	0.64	0.35	14449	-14443	14475
	Model5*	0.93	0.16	-0.99	0.08	0.21	0.44	14420	-14410	14463
	Model1	0.20				0.80	0.20	14349	-14345	14367
	Model2*	0.04	0.08			0.88	0.08	14313	-14307	14341
KR120	Model3*	0.23	0.14	1.00		0.46	0.56	14619	-14611	14656
	Model4*	0.06			0.08	0.86	0.06	14327	-14321	14355
	Model5*	1.00	0.72	-1.00	0.00	0.13	0.09	16224	-16214	16270

W0: birth weight, W60: weight at 60 days, W120: weight at 120 days, W180: weight at 180 days, DWG60: daily weight gain from birth to 60 days, DWG120: daily weight gain from birth to 120 days, KR60: Kleiber ratio at 60 days, KR120: Kleiber ratio at 120 days, σ_a^2= direct genetic variance, σ_m^2 = maternal genetic variance, $\sigma_{a,m}$ = direct-maternal gentic covariance, σ_{pe}^2 =maternal environmental variance, σ_e^2=residual variance, h^2=heritability, m^2 =maternal heritability, $r_{a,m}$=direct-maternal genetic correlation, pe²=maternal environmental proportion of total variance, e^2 = residual proportion of total variance, -2LogL: twice the the maximized value of the loglikelihood function, AIC: Akaike Information Criteria, BIC: Bayesian Information Criteria, *Modeli**: did not converged termined according to (σ_e^2), AIC, BIC and -2LogL values, and it was also taken into account whether the estimated parameters were within the biological limits. When these four criteria are considered together, Model 1 the simplest model for each trait was chosen and bivariate analyses were performed to estimate covariance between traits. The variance estimates obtained from univariate analyses were used as prior values in bivariate analyses.

Heritabilities

The direct heritability estimates, h^2, for all traits with the selected model (Model 1) are given in Table 4 (on diagonal). The highest estimate was obtained for W180 (0.39) followed by W0 (0.27), W60 (0.23) and W120 (0.22). The h^2 of 0.27 for W0 was quite lower than 0.52 reported by Supakorn and Pralomkarn (2012). The h^2 for W60 (0.23) was smaller than 0.38 and 0.31 for goats by Supakorn and Pralomkarn (2012) and Tesema (2020), and smaller than 0.31 for Boer goat (Menezes et al., 2016) and 0.26 for Boer x Central Highland goat (Supakorn and Pralomkarn, 2012). However, the h^2 was similar to the estimates reported in sheep (Abegaz et al., 2005; Rashidi et al., 2008), and to the estimates 0.21 for Naeini goat (Baneh et al., 2012) and 0.22 for Boer goat (Zhang et al., 2009), but higher than 0.18 for Jamunapari goat (Rout et al., 2018). The h^2 for W180 (0.39) is larger than the estimate of 0.16 by Tesema (2020). This study showed that there was enough direct additive genetic variance for post-weaning weight (W180) and this could be used for selection. However, only slow genetic improvement would be reached for weaning weight (W60 or W120) through selection. Rout et al. (2018) stated that different estimates of heritability could be the results of the model, the management and the recording system, the rate of inbreeding, and the data structure. Thus, in this study, the lower h^2 for W0, W60 and W120 can be attributed to the on ongoing intense selection in Hairy goats in that region and also the differences in management from flock to flock. Moreover, lower estimate of h^2 might be based upon that the flock owners have been unwillingness to exchange billy-goat, consequently this might be decreased the additive genetic variance but increased inbreeding.

The h^2 for KR60 (0.37) in the present study were similar to the estimates 0.35 and 0.32 by Supakorn and Pralomkarn (2012) and Tesema (2020), respectively, but higher than 0.27 reported by Gupta et al. (2016) for Mehsana goat. However, the estimate of h^2 for KR60 is higher than those reported by Ghafouri-Kesbi et al. (2011) in Zandi sheep (0.10), Rashidi et al. (2008) in Kermani sheep (0.07), and Eskandarinasab et al. (2010) in Afshari sheep (0.13).

Genetic and Environmental Correlations

The estimates of additive genetic (above diagonal) and environmental correlations (below diagonal) among growth traits from the bivariate analyses are given in Table 4. The genetic correlations for W0 with all other traits were positive and moderate, and ranged from 0.10 (W0-W180) to 0.41 (W0-W60 and DWG60) in the current study. In addition, the environmental correlation values for W0 with all other traits were negative but very small and ranged from -0.01 (W0-W180) to -0.08 (W0-all other traits). These moderate positive genetic cor-

Table 4. Genetic (above diagonal) and environmental (below diagonal) correlation among the growth traits from bivariate analyses, and heritabilities (on diagonal).from single trait analyses.

	W0	W60	W120	W180	DWG60	DWG120	KR60	KR120
W0	**0.27**	0.41	0.18	0.10	0.41	0.20	0.31	0.19
W60	-0.08	**0.23**	0.58	0.38	1.00	0.59	1.00	0.59
W120	-0.08	0.76	**0.22**	0.87	0.58	1.00	0.57	0.99
W180	-0.01	1.00	1.00	**0.39**	0.34	0.88	0.24	1.00
DWG60	-0.08	1.00	0.76	1.00	**0.23**	1.00	1.00	0.59
DWG120	-0.08	0.77	1.00	1.00	0.67	**0.21**	0.58	1.00
KR60	-0.08	0.99	0.79	1.00	0.99	0.80	**0.37**	0.64
KR120	-0.08	0.78	0.98	0.94	0.77	0.98	0.82	**0.20**

W0: birth weight, W60: weight at 60 days, W120: weight at 120 days, W180: weight at 180 days, DWG60: daily weight gain from birth to 60 days, DWG120: daily weight gain from birth to 120 days, KR60: Kleiber ratio at 60 days, KR120: Kleiber ratio at 120 days relation values and negative small environmental values suggested that heavier kids at birth will tend to have heavier weights at later ages. The genetic and the environmental correlations among all other growth traits were positive and higher. The genetic correlations were 0.58 and 0.87 for W60-W120 and W120-W180, respectively, and the environmental correlations were 0.76 and 1.00 between the same traits, respectively. These values mean that heavier kids at present age will likely to be heavier at the subsequent ages.

The genetic correlations obtained in this study (among W0-W60-W120-W180) are lower than the estimates for Draa goat (Boujenane and Hazzab, 2008), Markhoz goat (Rashidi et al., 2011), Arsi-Bale goat (Bedhane et al., 2013), Khari goat (Bhattarai et al., 2017), Boer-Central Highland goat (Tesema 2020). In contrast to genetic correlation, the environmental correlations among the same traits were very high (ranging from 0.76 to 1.00, except for W0. Bourdon (2014) stated that the high genetic correlation among these traits might be the result of pleiotropy. However, in our study, the environmental correlations were much higher than the genetic correlations, meaning no sign of a pleitropic effect.

The genetic and environmental correlations for KR60 with W60 and DWG60 were 1.00 and 0.99, respectively. Moreover, h^2 were 0.23, 0.23 and 0.37 for W60, DWG60 and KR60, respectively. Therefore, in order to make more genetic improvement on weaning weight (W60), increased selection for KR60 would be the better choice in a selection program of hairy goats in Türkiye, instead of choosing breeder goats based on W60 or DWG60. This will allow culling in early stage of life of bucks to reduce the related cost. On the other hand, this situation does not hold for growth after weaning until 120 days of age due to the reason that the heritability estimates were almost the same for W120 (0.22), DWG120 (0.21) or KR120 (0.20). Based on these estimates for KR60, it can be stated that growth efficiency for KR60 is moderately heritable (0.37) and KR60 can be used in genetic improvement programs for increased growth efficiency (Ghafouri-Kesbi et al., 2011).

Phenotypic and Genetic Trends

The phenotypic and genetic trends for growth traits are given in Table 5. This exhibited that W0, W120, DWG120 and KR120 decreased phenotypically and genetically by -0.03 and -0.01, -0.15 and -0.14, -1.06 and 1.27, -0.05 and -0.05 kg/year, respectively, while W60, W180, DWG60 and KR60 increased by 0.35 and 0.03, 1.18 and 0.07, 6.02 and 0.55, 0.40 and 0.06 kg/year, respectively. Similar results were reported in previous studies for W0 (Tesema 2020 in Boer x Central Highland goat) and for W60 and W180 (Rout et al., 2018 in Jamunapari goats). Animal model (BLUP) use all available information about an individual to estimate its breeding value before selection. As a result, the negative genetic trend for W0 but the positive genetic trend for W60 and W180 could be attributed to the presence of the selection for kids that the selection applied to this population had some restriction in the selection index that 1) W0 was restricted to be unchanged 2) W60 received greater emphasis in order to be increased.

Table 5. Phenotypic and genetic trends for growth traits

	Phenotypic		Genetic	
	Intercept	Slope	Intercept	Slope
W0	3.77±0.078**	-0.03±0.005**	0.09±0.023**	-0.01±0.001**
W60	6.59±0.518**	0.35±0.033**	-0.54±0.240*	0.03±0.015*
W120	22.68±0.609**	-0.15±0.040**	2.57±0.338**	-0.14±0.022**
W180	11.45±1.134**	1.18±0.069**	-1.06±0.473*	0.07±0.029*
DWG60	52.04±8.352**	6.02±0.518**	-9.04±4.005*	0.55±0.248*
DWG120	157.87±4.966**	-1.06±0.325**	22.58±2.862**	-1.27±0.187**
KR60	16.07±0.606**	0.40±0.038**	-1.06±0.305**	0.06±0.019**
KR120	15.40±0.202**	-0.05±0.014**	0.91±0.113*	-0.05±0.007**

*P<0.05, **P<0.01

W0: birth weight, W60: weight at 60 days, W120: weight at 120 days, W180: weight at 180 days, DWG60: daily weight gain from birth to 60 days, DWG120: daily weight gain from birth to 120 days, KR60: Kleiber ratio at 60 days, KR120: Kleiber ratio at 120 days,

CONCLUSION

Birth weight (W0) and weaning weight (W60) are regularly documented for the purpose of enhancing the pre-weaning growth rate. One suggested and used index to assess the energy efficiency of goats is the KR60, which provides a decent indication of how economically an animal is growing. Additionally, KR60 can be used as a feed efficiency indicator for preweaning growth characteristics in the selection index. This research shows that birth year-season, gender, and birth type have an impact on W60 and KR60 in this population of goats.

The estimates of genetic parameters indicated that this goat population had the genetic potential to improve its growth traits. Consequently, it is feasible to execute a breeding program in this goat population if an accurate recording of data for village conditions are established, and also providing that measures are taken to ensure that breeders routinely adopt the exchange of billy goats for breeding porposes.

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CONFLICT OF INTEREST

None of the authors of this article has any conflict of interest.

ETHICAL STATEMENT

This study does not present any ethical concerns

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